

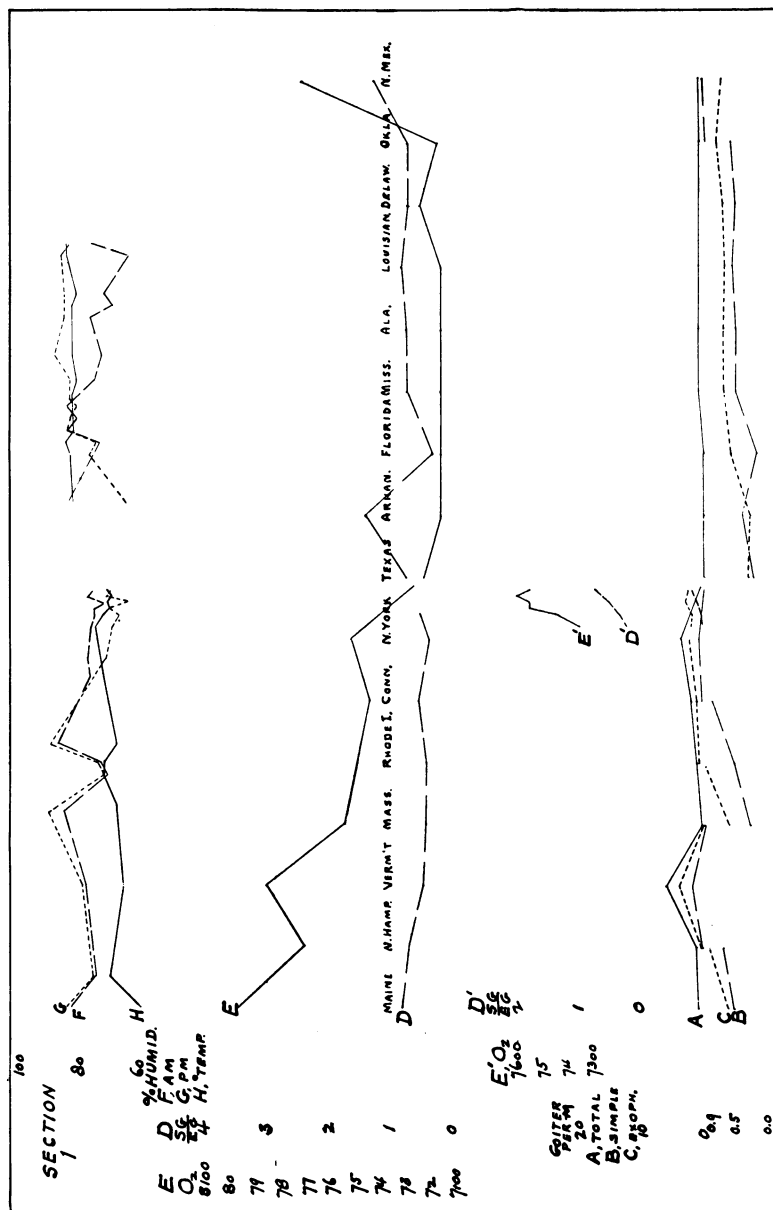
THE INFLUENCE OF SOLAR RADIATION ON THE
DISTRIBUTION AND PREVALENCE OF
EXOPHTHALMIC GOITER IN THE
UNITED STATES.*

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When a relationship between the sun and biological effects is apparent, questions arise as to how the effect is brought about, but there is never any confusion as to which is cause and which is effect. In previous papers I have pointed out that in the United States,^{1 4} India² and New Zealand,³ deficiency of sunshine in winter corresponds with the endemicity of goiter, and indeed with iodine deficiency of soil and water. In another paper⁵ a relationship was shown to exist between (a) variation in exposure to sunshine during the annual cycle and (b) the prevalence of pellagra.

In this paper it will be shown that, according to the report and definitions of the United States Draft Board,⁶ in males in the third decade the occurrence of exophthalmic goiter shows variations in the same order of magnitude as simple goiter in the various sections of the country, and that in general the ratio of simple goiter to exophthalmic goiter varies directly with the prevalence of simple, exophthalmic and total goiter. Where goiter is least prevalent, the ratio of exophthalmic goiter to simple goiter is highest (and the prevalence of pellagra is greatest). It will also be shown that the ratio of exophthalmic to simple goiter corresponds very closely to certain known effects of temperature and humidity on the rate of oxygen consumption of normal men under experimental conditions. The relationship between the primary cause and the end results will not be obscured by an attempt at this time to discuss the mechanisms involved. Freedom in interpretation is employed in the conclusions only to the extent of accepting the well-known effects of thyroidec-tomy and the established fact of a low iodine content of the gland in Graves' disease.

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Within recent years at the Pittsburg Laboratory of the United States Bureau of Mines⁷ it has been shown that the perception of temperature by the human body depends upon a combination of the influences of temperature, humidity and wind. The perceived temperature has been designated the "effective temperature." In a later report McConnell, Yaglou and Fulton⁸ showed that the oxygen consumption of normal men is lowest at effective temperatures of 76° to 80° F. inclusive, these effective temperatures representing the corresponding dry bulb temperatures at 100 per cent relative humidity. Ignoring the effect of wind, higher temperatures yield higher effective temperatures, lower temperatures yield lower effective temperatures, and lower per cent of humidity yields lower effective temperatures in any range of temperature. But effective temperatures both higher and lower than 76° to 80° are characterized by oxygen consumption increasing with departure from the critical low oxygen consumption of 76° to 80° effective temperature.

Thus, by combining the two sets of data, it is possible to determine the approximate oxygen consumption of normal men at varying degrees of temperature and humidity, and thus is obtained a measure of the normal rate of metabolism for any given geographical area where the climatic factors are known and where they are within the limits of the factors experimentally observed. Obviously the experimental studies referred to do not allow for acclimation, but the results, within the range of temperatures applicable to the United States, are in accord with the established tendency for the normal oxygen consumption to be relatively low in warm climates.

As seen in Chart 1, the curves of simple (B) and exophthalmic goiter (C) vary so as to show (in males in the third decade) a general order of prevalence common to the two diseases. It may be said that both are highest in the Pacific Northwest and lowest in the Atlantic Southeast.

When the exact ratio of simple goiter to exophthalmic goiter is examined, it is seen that the ratio is reversed in the Northwest as compared with the Southeast (D). The ratio of exophthalmic goiter to simple goiter is high in the Southeast and low in the Northwest, with a resulting central area where the ratio is practically 1 to 1.

If states are considered by sections according to the divisions made by the Draft Board, the correlation between D', the simple-

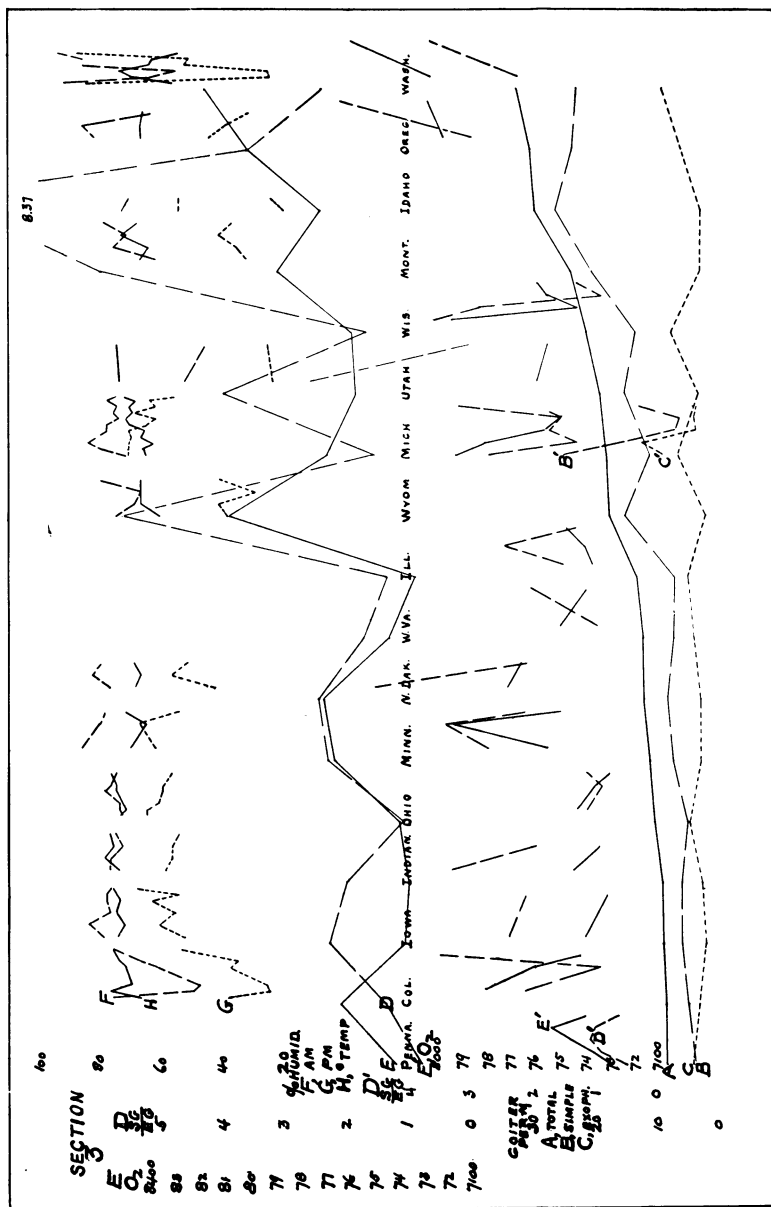
exophthalmic ratio, and E' , oxygen consumption, holds for sections of states as for states. The same may be said of cities reported by the Draft Board as units.

Regarding the subjects of simple and exophthalmic goiter as the goiter material reacting to the goitrogenic influences of a given area, approximately 50 per cent show exophthalmic goiter under the conditions of temperature and humidity in July mean for the United States. If the climatic conditions tend to lower oxygen consumption in normal men, more than 50 per cent show exophthalmic goiter, introducing something of a paradox in view of the increased oxygen consumption characteristic of the disease. If the climatic conditions tend to higher oxygen consumption in normal men, less than 50 per cent show exophthalmic goiter. The variations in the ratios of simple and exophthalmic goiter (D) accord sufficiently closely with the variations in normal oxygen consumption (E), and the comparisons are applicable to sufficiently small divisions of territory (D' and E') as to make the relationship carry a conviction of significance. Rate of oxidation is the essential feature in both sets of data. Increased rate of oxidation in toxic goiter under conditions of temperature and humidity that induce decreased rate in normal men represents, therefore, an abnormal reaction. The occurrence of exophthalmic goiter in the same order of magnitude as simple goiter suggests that measures that prevent simple goiter may have an important bearing in the prevention of exophthalmic goiter. There would seem to be here a promising basis for the further investigation of the relationship between non-toxic and toxic goiter.

CONCLUSIONS.

Conditions of temperature and humidity which, under experimental conditions and without acclimation, tend normally to decreased rate of oxygen consumption are associated with an increased ratio of exophthalmic goiter to simple goiter in young men as reported by the United States Draft Board.

As shown by the prevalence of the two diseases in the same order of magnitude in the various sections of the United States, the conditions giving rise to simple goiter, by the third decade have altered the reactivity of the thyroid gland in certain individuals with or without the development of simple goiter, which alteration renders



the individual more liable to the development of exophthalmic goiter. This liability tends to be realized under conditions of temperature and humidity tending to lower basal metabolism in normal men.

Though the thyroid alteration involves or tends to iodine exhaustion, there remains in or pathologically develops in the thyroid gland, as shown by the effects of thyroidectomy in exophthalmic goiter, a substance, in itself or in collaboration with another substance, capable of increasing tissue oxidation abnormally, or of inhibiting substances which normally serve as a brake on the rate of tissue oxidation.

Through some unknown mechanism climatic conditions which normally depress the oxidation rate tend to activate in the subject of exophthalmic goiter substances which promote the rate of tissue oxidation or tend to inhibit the activity of substances which normally act as a brake on the rate of tissue oxidation.

CHART 1, SECTION 1.

Chart 1 is divided into three sections, Nos. 1, 2 and 3. The order of arrangement of states is according to total goiter reported by the United States Draft Board,⁶ except for the New England group of states, which have been segregated for reasons given below.

In each of the sections of the chart the curves represent:

- A. Total goiter, ratio per 1000 men, by states (continuous line).
- B. Simple goiter, ratio per 1000 men, by states (long dash line).
- C. Exophthalmic goiter, ratio per 1000 men, by states (short dash line).
- D. Ratio of simple goiter to exophthalmic goiter, by states (long dash line).
- E. Normal oxygen consumption mean for July (continuous line).

The sources of data for this curve are as follows:

- (a) For temperature mean for July and for relative humidities mean for July, Bulletin W, U. S. Weather Bureau, using for each state the data for all stations reporting from the state. Mean July relative humidity is determined by taking the mean of morning and evening relative humidity.
- (b) "Effective temperatures" have been determined by applying the climatic data just described to the standards as figured by Huntington,⁷ and these have been translated into figures for oxygen consumption of normal men for varying effective temperatures according to the report of McConnell, Yaglou and Fulton.⁸
- F. Relative humidity at approximately 8 A.M. mean for July (long dash line).
- G. Relative humidity at approximately 8 P.M. mean for July (short dash line).

H. Temperature mean for July (continuous line).

The New England states have been transferred from their proper sequence in prevalence of total goiter for the purpose of showing the contrast with other parts of the country as to diurnal variations in relative humidity, curves F and G. In New England, morning and evening humidity are practically the same. The effect of humidity, therefore, in its influence on "effective temperature" is operative practically through the 24-hour cycle at a fixed intensity, thus involving duration as well as intensity, and the proportion of exophthalmic goiter to simple goiter in New England is higher than would be indicated by the curve of oxygen consumption. In Florida the same conditions of humidity obtain, but the temperature is within the range in which variations in humidity do not influence the effective temperature and oxygen consumption as reported by McConnell and his collaborators.⁸

CHART 1, SECTION 2.

Average conditions in the United States with respect to temperature and humidity prevail generally in the central area. There is an average fall in humidity from morning to evening of approximately 20 per cent (H, F, G).

D'. Ratio of prevalence of simple goiter to exophthalmic goiter, by sections of states (long dash line). See also Sections 1 and 3.

E'. Normal oxygen consumption mean for July, by sections of states (continuous line). See also Sections 1 and 3.

CHART 1, SECTION 3.

In contrast to climatic conditions in New England are those in the Pacific Northwest states. In this area not only is the morning humidity (F) lower than in New England, but also the evening humidity (G) is very much lower than that of the morning, and this fall in humidity develops early in the day. Thus the conditions tending to high oxygen consumption in normal men are favored with respect to their duration through the 24-hour cycle, and the ratio of simple goiter to exophthalmic goiter tends to be higher than would be indicated by the curve of oxygen consumption (Wyoming, Utah, Montana, Idaho).

B'. For the state of Michigan, by sections, prevalence of simple goiter (long dash line).

C'. For the state of Michigan, by sections, prevalence of exophthalmic goiter (short dash line).

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DISCUSSION.

DR. JOHN P. SAWYER: For many years I was interested in this question of exophthalmic goiter, calling attention to it in Cleveland as being the center of goiter belts. The remark of the influence of humidity is something which is, I think, experimentally demonstrable to anyone who will take the pains to watch the daily reactions of the individuals.

The drier atmosphere is usually a time of considerable comfort and well-being for these people. The oncoming of a storm can be recognized by those sufferers as imminent some hours before it actually comes, though the sun may be shining and no clouds are in the sky.

I have been intensely interested in the presentation of the paper, which has taken up the study of basal metabolism, as it is now called, and the fact of the influence of humidity is one that I wanted to emphasize, and also the fact that in all probability is concerned with the physiological reaction of the skin upon the nervous system.

The stimulus of evaporation is a very considerable one and affects many of the vasomotor functions of the body to which the people who have exophthalmic goiter are especially subjected, and the favorable effect upon incomplete cases of the disorder is seen in such instances where helio or hydrotherapy is used. The proper use of hydrotherapy is very often of great help to these individuals, those observations simply emphasizing, I believe, the influence of the humidity to which Dr. Smith has called attention.

DR. THOMAS: Just one word which this paper brings out: it is very interesting to have the etiology of exophthalmic goiter on some basis other than

traumatic psychic trauma. The title, "The Influence of Solar Radiation," brings up a paper that I heard not long ago in which an experiment was done with growing chickens. This paper was given at the Medical Center in New York. Growing chickens were exposed to the light of ultra-violet lamps over a period of several months, and a controlled series was kept under the same light with a screen which cut out the ultra-violet rays. The ultra-violet ray chickens developed normally and the controlled series developed bodily development normally, but the thyroid gland was a little enlarged and the pathological sections showed a change which was identical to the change seen in exophthalmic goiter with atrophy and hyperplasia of the cells.

The conclusions from that paper were reached that it might possibly not be cutting out the ultra-violet that did this, but it might possibly have something to do with the infra-red rays of the chickens in the controlled series which developed the type of glands seen in exophthalmic goiter. I would like to ask Dr. Smith whether he believes that the variations in climate that he has spoken of might possibly have some relation to the actual solar radiation and the variety of solar radiation.

DR. JAMES H. SMITH: In answer to Dr. Thomas, I am reminded that the work he refers to in chickens was reported from Germany with reference to rats in January, 1931. In that article Bergfeld reported his work on rats, and worked exclusively with the ultra-violet wave lengths. By cutting off those wave lengths he produced the hyperplastic thyroid quite comparable to the one to which you refer, which reminds me to say that so far as I have any knowledge at all, the suggestion is that perhaps the ultra-violet is the most significant wave length in connection with these thyroid changes.